LIMITATIONS FOR THE USE OF ANTHROPOMORPHIC PHANTOMS IN X-RAY DIAGNOSTICS

F. Kossel
Institut für Strahlenhygiene des Bundesgesundheitsamtes
Ingolstädter Landstr. 1
8042 Neuherberg

Radiographs of the anthropomorphic phantom used in our laboratory for dosimetric purposes show remarkable visual deviations in bone absorption compared with x-ray images of the human body taken in the same position. This is demonstrated by radiographs of the lumbar spine from our phantoms in anterior, posterior and lateral positions. The radiation absorption within the single vertebrae is lower than in the surrounding soft tissue. This anthropomorphic phantom is an Alderson-Rando phantom which is composed of different plastic material radioequivalent to corresponding human tissues as muscles, lung tissue, etc.. The phantom contains a natural skeleton. Apparently air is being retained in the bone structure during the preparation procedure. To confirm the observation, the radiation attenuation was measured under small beam conditions (1) through one section with x-rays of diagnostic qualities between 50 and 110 kv. The radiation was filtered in such a way that the half value layer is the same as that for a homogeneous radiation of half the energy, so called "normal radiation". From radiographs we know sections of the phantom in which one vertebra is covering the entire thickness. In our phantom, this is section 25.

The radiation is attenuated by the bone structure itself and the soft tissue filling the trabeculae of the bone. The entrance dose d_o is reduced to

$$D = D_0 e^{-\mu_b d_b} e^{-\mu_s d_s}$$

where d_b of the bone material and d_s of the soft tissue are the thickness $d = d_e + d_s$, and μ_b and μ_s the relevant linear attenuation coefficients. If the soft tissue is replaced by air, the second exponential term is approximately 1, due to the low density of air which is nearly by a factor 1000 lower than the density of the bone marrow tissue. In this extreme case, none of the viscous plastic substances have infiltrated the bone structure during the preparation procedure. This is valid for our phantom, as can be seen from the experimental results. Perhaps it is a casual event that for the lumbar spine inhomogeneities of the bone are compensated by air-filled gaps in such a way that the phantom works like a homogeneous phantom. However, this may contribute to the fact that deviations from natural body composition are not easy to discover, especially when dosimeter probes are used which integrate over a larger area. The x-ray film is the best indicator for detecting small local changes in absorption properties.

This type of anthropomorphic phantom is widely used in many laboratories, also for research in the field of x-ray diagnostics.

The observed deviation may cause errors, if the results from dose measurements are used for dose estimates inside or behind bone in human bodies. A review of published information on construction details confirms our observation. It is described that skeletons are received in a dried condition and that skeletal preparation with soft tissue equivalent plastic material cannot suffuse bone as completely as in the living body (2).

This presentation is meant to alert the attention of users of the same type of phantom showing similar or comparable deviations in relation to real body absorption.

(1) DIN 6845, Teil 1: Prüfung von Strahlenschutzstoffen für Röntgen- und Gammastrahlung; Röntgenstrahlung bis 400 kV, Ausgabe Februar 1980

(2) Alderson-Rando Phantom System, Technical Bulletin No. 431 Januar 1969